SPINE AND SPINAL CORD INJURY IN MOTOR VEHICLE CRASHES: A FUNCTION OF CHANGE IN VELOCITY AND ENERGY DISSIPATION ON IMPACT WITH RESPECT TO THE DIRECTION OF CRASH: KEY DETERMINANTS OF THE PATTERN OF ASSOCIATED INJURIES AND PATIENT OUTCOMES. A CRASH INJURY RESEARCH ENGINEERING NETWORK (CIREN) STUDY

JOYCE A. SMITH, MS,
JOHN H. SIEGEL, MD,
SHABANA Q. SIDDIQI, MD
NEW JERSEY MEDICAL SCHOOL CIREN CENTER

In addition to the NJ CIREN Center, data included was collected by 9 other CIREN Center Principal Investigators:

- University of Alabama Birmingham
  - Loring W. Rue, MD
- Children's National Medical Center
  - Martin Eichelberger, MD
- Honda Inova Fairfax
  - Samir Fakhry, MD
  - Dorraine D. Watts, PhD
- Harborview Injury Prevention and Research Center
  - Charles Mock, MD
  - Fred Rivara, MD
  - David Grossman, MD
- William Lehman Injury Research Center
  - Jeffrey S. Augenstein, MD

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- University of Michigan
  - Stewart Wang, MD
  - Larry Schneider, PhD
- National Study Center for Trauma and EMS
  - Patricia Dischinger, PhD
  - Andrew Burgess, MD
  - Jim O'Connor, MD
- San Diego County Trauma System
  - A. Brent Eastman, MD
  - David B. Hoyt, MD
  - Gail Cooper, PhD
- MCW - Froedtert Hospital
  - Thomas Gennarelli, MD

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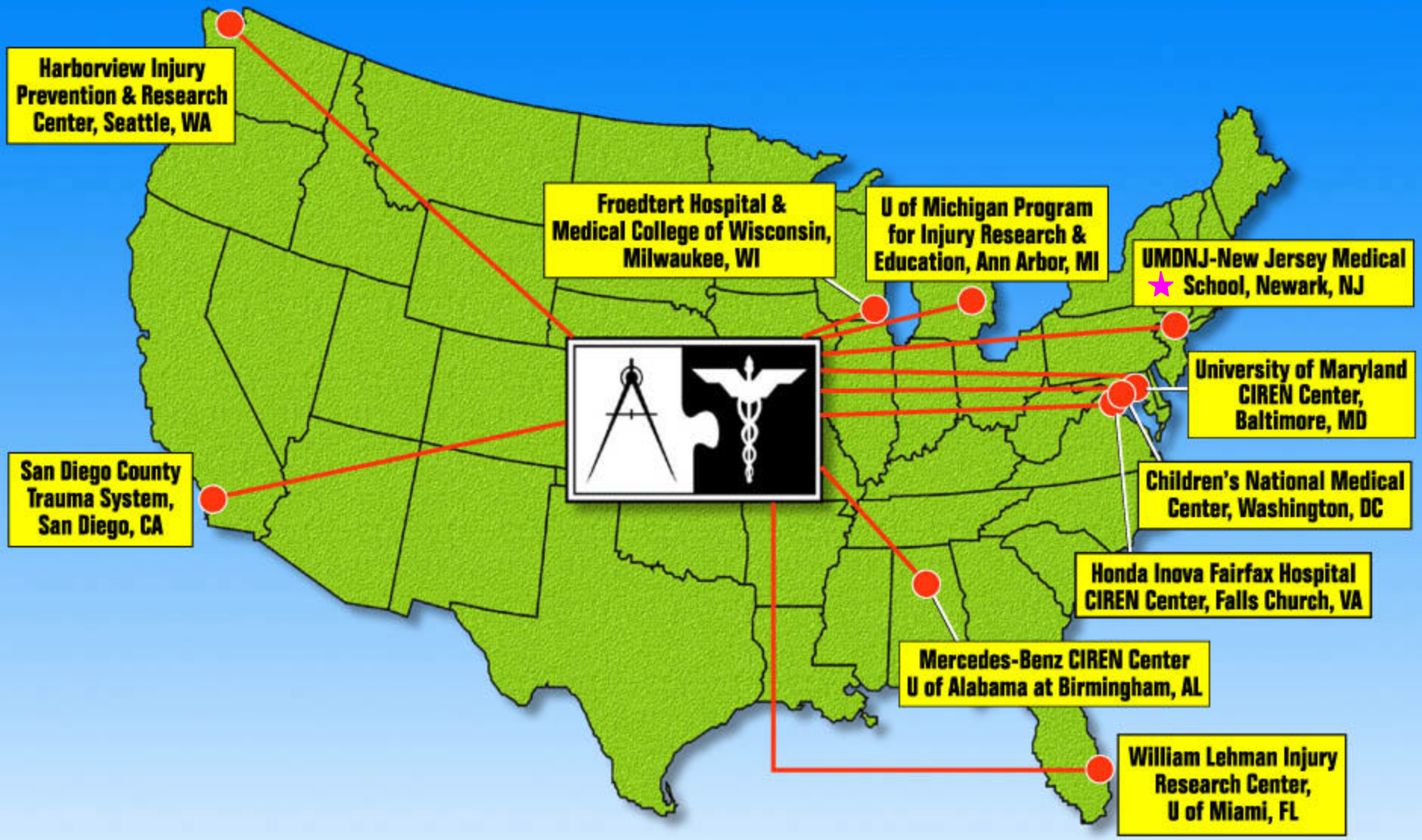

INTRODUCTION I

THE CONSEQUENCES OF SPINE AND SPINAL CORD INJURY WERE FIRST DESCRIBED IN THE SMITH PAPYRUS, FROM THE OLD KINGDOM OF EGYPT (3000-2500 BCE).

"If thou examinest a man having a dislocation in a vertebra of the neck, shouldst thou find him unconscious of his two arms (and) his two legs on account of it, while his phallus is erected on account of it, (and) urine drops from his member without his knowing it…"; it is "An ailment not to be treated."

GALEN, A PHYSICIAN IN 2ND CENTURY AD, DEMONSTRATED PARALYTIC EFFECTS OF CERVICAL SPINAL CORD TRANSECTION AT DIFFERENT LEVELS.

He showed that transection of the cord below the 4th cervical vertebra allowed some voluntary respiration, but transection above the 3rd vertebra abolished respiration by paralysis of the diaphragm.

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INTRODUCTION II

PRIOR TO THE MECHANIZED AGE, SPINAL COLUMN AND SPINAL CORD INJURIES WERE MOST COMMONLY RELATED TO FALLS OR SECONDARY TO BLOWS TO THE BACK. WITH THE ADVENT OF THE MODERN ERA, THE MAJOR CAUSE OF NON-PENETRATING SPINE INJURIES HAS BEEN CONSEQUENT TO MOTOR VEHICLE CRASHES. RECENT REPORTS FROM THE UK SHOWED 14% OF CAR CRASH OCCUPANTS SUSTAINED A SPINE FRACTURE (SF). A CANADIAN STUDY HAS SHOWN THAT 59% OF THEIR SF CASES HAD A CERVICAL SF DUE TO A MVC.

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MATERIALS & METHODS I

PATIENT:

1) AGE, SEX, HEIGHT & WEIGHT
2) DIRECTION OF CRASH FMVC OR LMVC
3) OCCUPANT VEHICLE (V1) VS OTHER VEHICLE (V2) OR NON-VEHICLE (FO)
4) SEAT-BELT AND AIRBAG DEPLOYMENT
5) SURVIVAL OR DEATH STATUS
6) PATIENT OR NEXT OF KIN INFORMED CONSENT OR
7) MEDICAL EXAMINER'S AUTHORITY FOR SCENE FATAL CRASHES
8) POLICE, EMS & HOSPITAL RECORDS
9) MEDICAL EXAMINER AUTOPSY REPORTS
10) PSYCHOSOCIAL EVALUATION IN HOSPITAL & FOLLOW-UP AT 6, 12 & 18 MONTHS

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MATERIALS & METHODS II

VEHICLE:

1) CRASH RECONSTRUCTION DATA FOR MECHANISM OF CRASH WITH SCENE DIAGRAM AND DETERMINATION OF PRIMARY DIRECTION OF FORCE (PDOF) ON SUBJECT VEHICLE (V1)
2) DELINEATION OF SITES OF DRIVER AND/OR FRONT SEAT PATIENT'S INJURY-PRODUCING CONTACT WITH PASSENGER COMPARTMENT STRUCTURES
3) COMPUTATION OF CHANGE IN VELOCITY ON IMPACT (DELTA V) ON V1 VEHICLE
4) COMPUTATION OF IMPACT ENERGY DISSIPATION (IE) ON V1 VEHICLE

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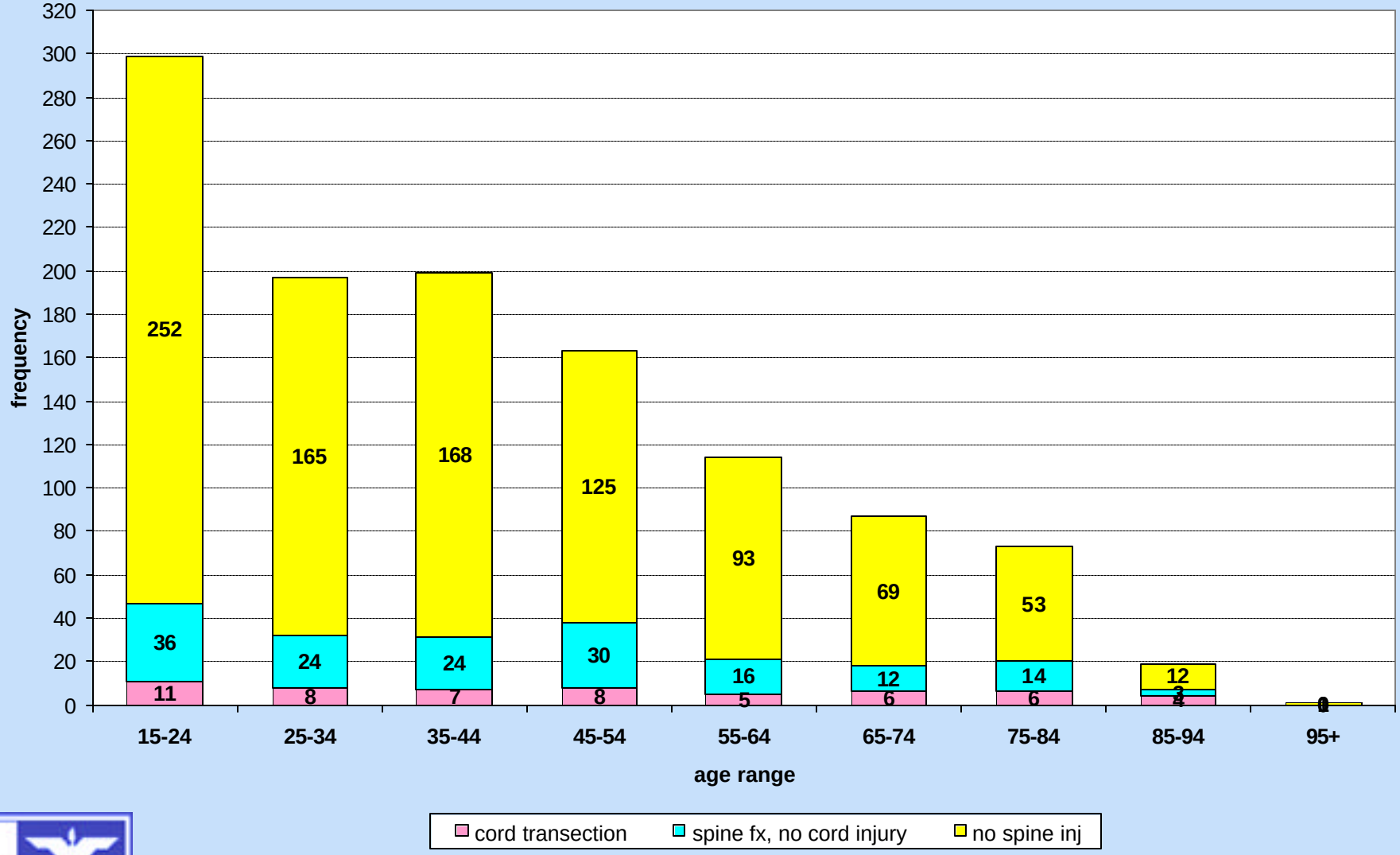
MATERIALS & METHODS III

CIREN DATA FROM 1152 ADULT DRIVERS OR FRONT-SEAT OCCUPANTS OF MOTOR VEHICLE CRASHES (MVCs) INVOLVING CARS OR SPORT UTILITY, VANS, OR LIGHT PICK-UP TRUCKS (SUVT). CRASHES WITH FULL ROLLOVERS, REAR-END COLLISIONS, OR EJECTED PATIENTS EXCLUDED. NO SIDE AIRBAGS IN SERIES. DATA SPAN PERIOD 1996-2003. ALL PATIENTS HAD AIS = 3, BUT WITHIN GROUP OF 1152 WERE 214 PATIENTS WITH SPINE FRACTURES (SF) OF AIS = 2. SOME PATIENTS HAD SPINE FRACTURES IN MORE THAN ONE ANATOMIC REGION SITE: (CERVICAL,THORACIC, OR LUMBAR).

701 FRONTAL MVCs (PDOF 340° - 0 - 20°) RESULTED IN 142 ANATOMIC REGIONAL SITES OF SF.

451 LATERAL MVCs (PDOF <340° -190° OR >20° -170°) RESULTED IN 101 ANATOMIC REGIONAL SITES OF SF.

Age Distribution of All MVC Cases
(N = 1152)



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TYPE OF MOTOR VEHICLE AND NATURE OF IMPACTING VEHICLE OR OBJECT IN 201 MVCs IN WHICH PATIENTS WITH SPINAL FRACTURE INJURIES WERE DRIVERS OR FRONT-SEAT PASSINGERS

FMVC:	V2=CAR	V2=SUVT	FIXED OBJECT
V1=CAR (N=77)	27%	18%	55%
V1=SUVT (N=36)	11%	22%	67%

LMVC:	V2=CAR	V2=SUVT	FIXED OBJECT
V1=CAR (N=76)	37%	33%	30%
V1=SUVT (N=12)	17%	25%	58%

IN FRONTAL CRASHES: REGARDLESS OF WHETHER V1 WAS A CAR OR SUVT, THERE WERE A DISPROPORTIONATE NUMBER OF CRASHES INTO FIXED OBJECTS, IE: BARRIERS, TELEPHONE POLES, OR TREES, WHICH RESULTED IN A SPINAL FRACTURE

IN LATERAL CRASHES: IF V1 WAS A CAR, THE INCIDENCE OF THE TYPE OF V2, OR IMPACT INTO A FIXED OBJECT WAS EVENLY DISTRIBUTED AS THE CAUSE OF THE SPINAL FRACTURE INJURY. HOWEVER, IF V1 WAS AN SUVT, A CRASH INTO A FIXED OBJECT WAS THE OVERWHELMING CAUSE OF THE SPINAL FRACTURE INJURY

COMPUTED CRASH DELTA Vs & IEs

FMVC:	MEDIAN	MEAN & SD	IE
N=701	45 KPH	47 ± 24.8 KPH	159,679 J

SPINE FRACTURE (SF) IN FMVC PATIENTS

CERVICAL SF	68 PATIENTS
THORACIC SF	35 PATIENTS
LUMBAR SF	39 PATIENTS

LMVC:	MEDIAN	MEAN & SD	IE
N=451	33 KPH	35 ± 19.2 KPH	103,794 J

SPINE FRACTURE (SF) IN LMVC PATIENTS

CERVICAL SF	64 PATIENTS
THORACIC SF	21 PATIENTS
LUMBAR SF	16 PATIENTS

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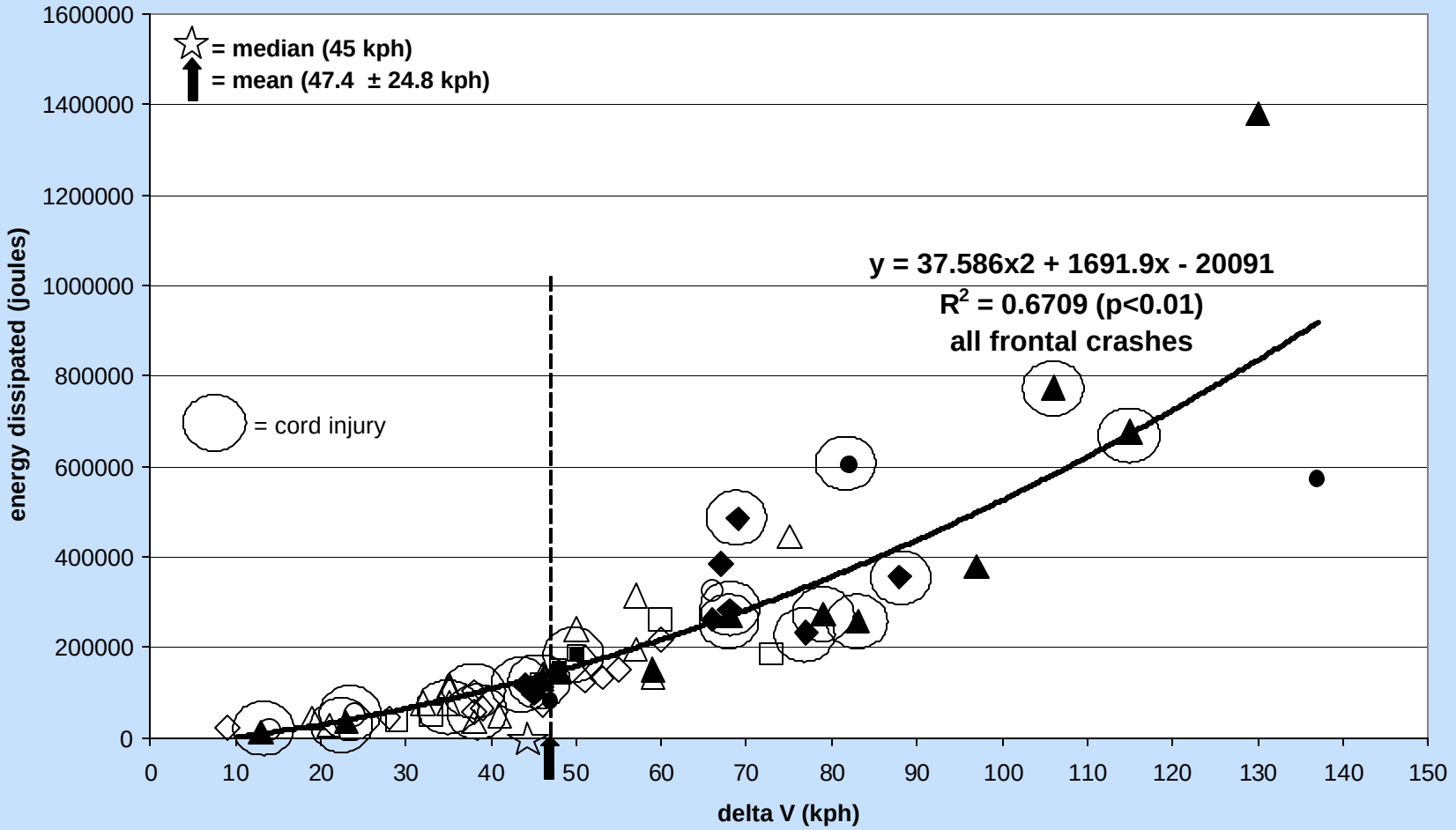
Patients With Frontal Cervical Spine Injuries by Restraint Use and Mortality



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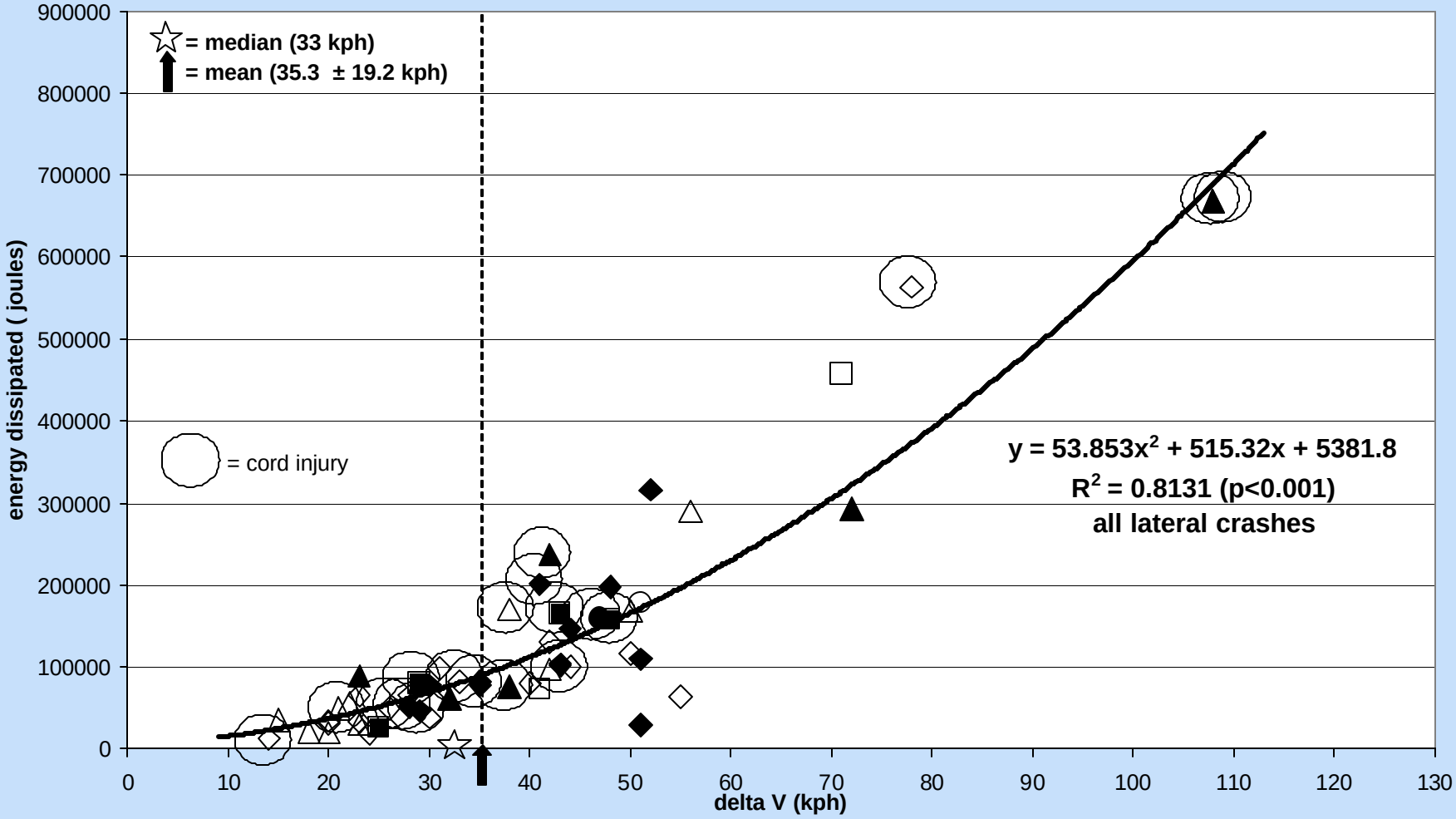
Patients With Lateral Cervical Spine Injuries by Restraint Use and Mortality



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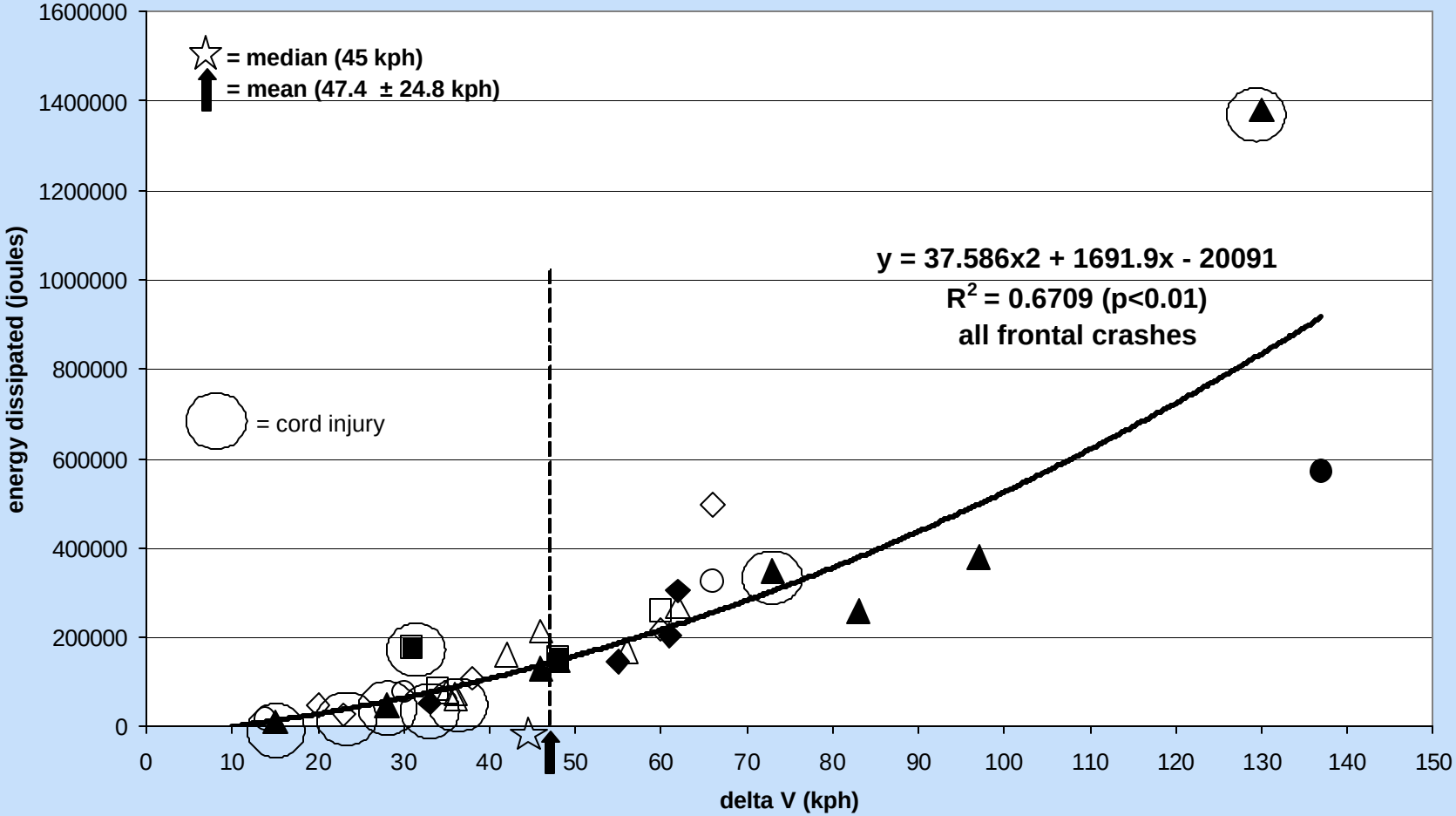
Patients With Frontal Thoracic Spine Injuries by Restraint Use and Mortality



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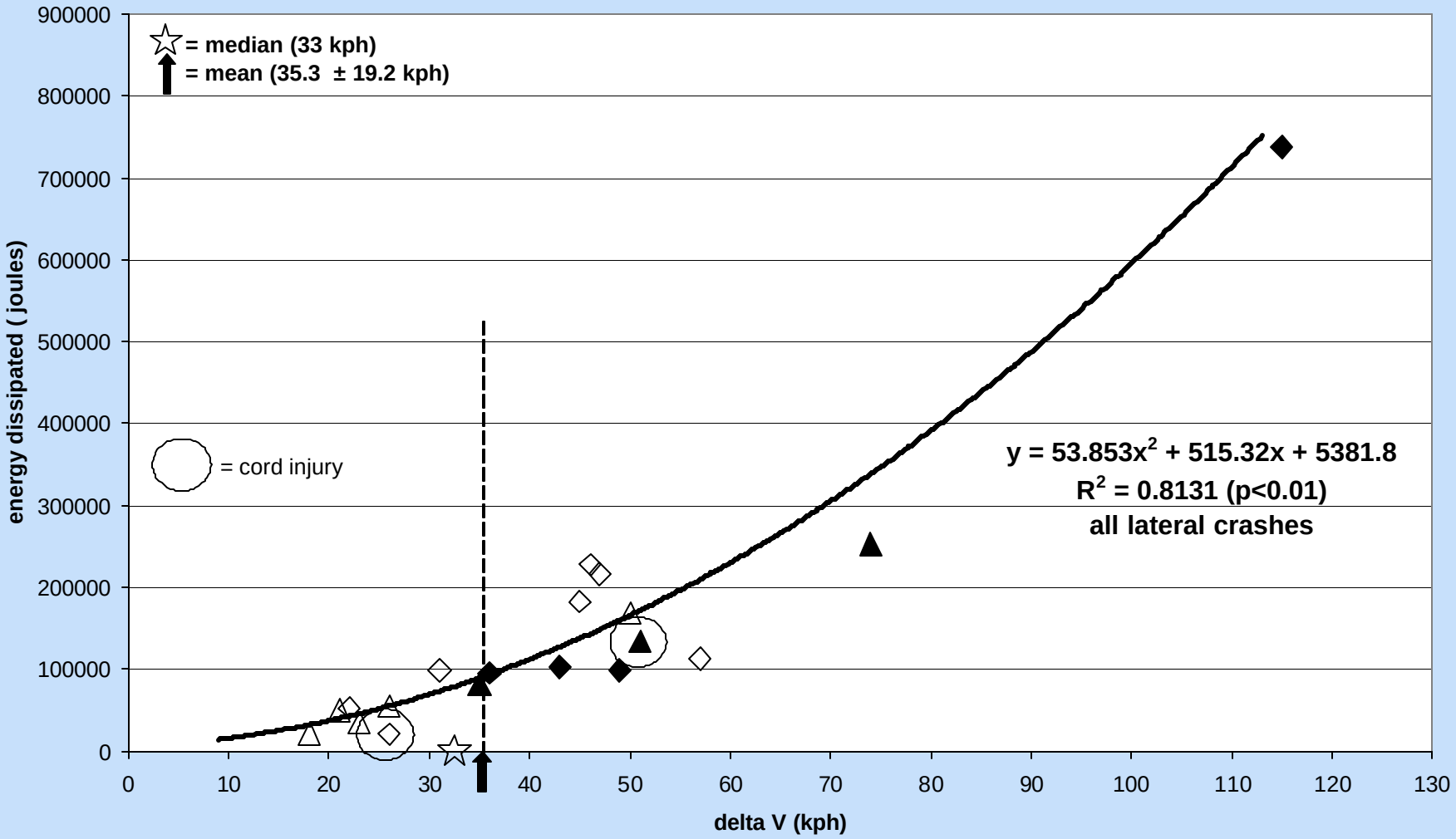
Patients With Lateral Thoracic Spine Injuries by Restraint Use and Mortality



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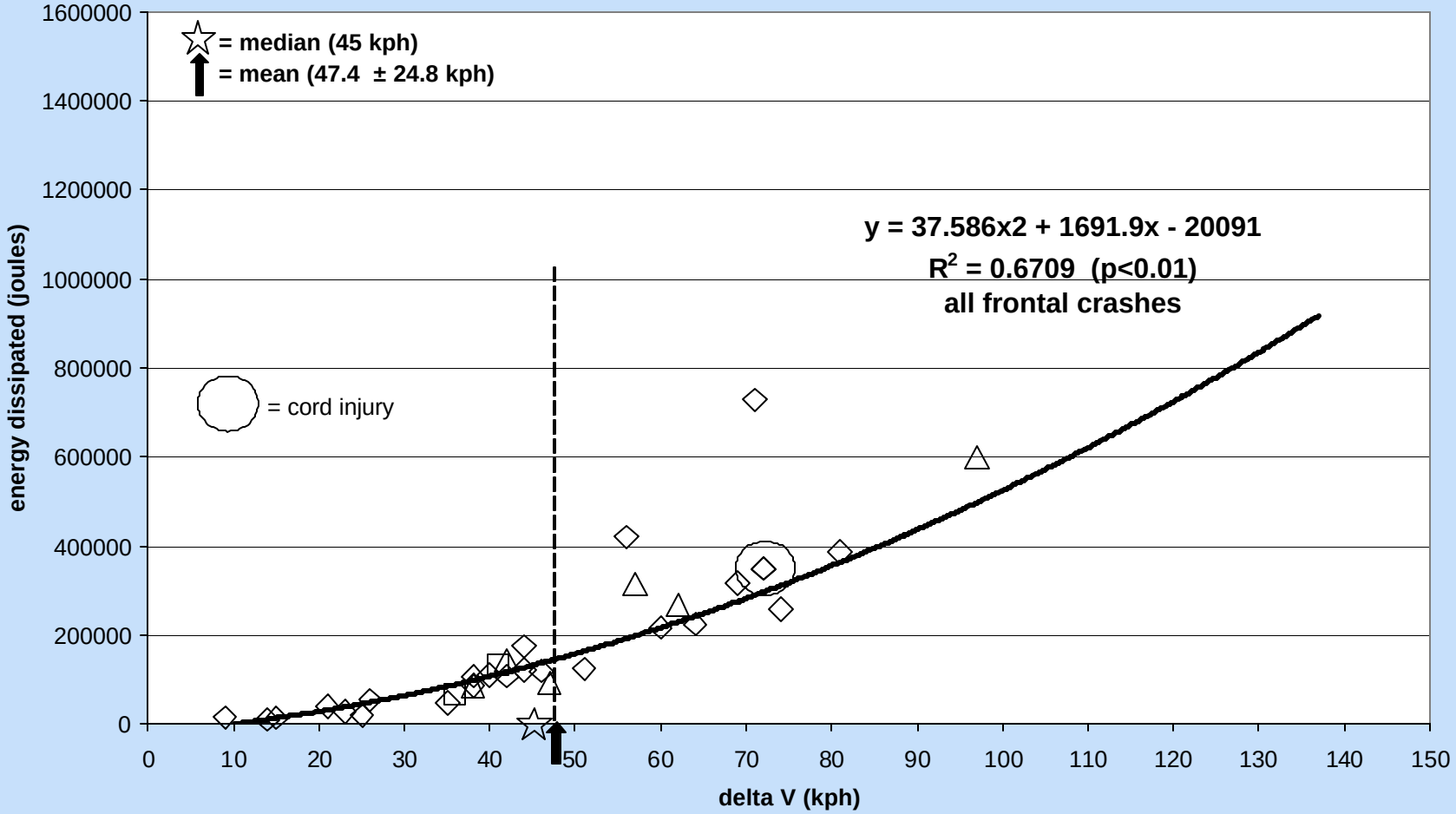
Patients With Frontal Lumbar Spine Injuries by Restraint Use and Mortality



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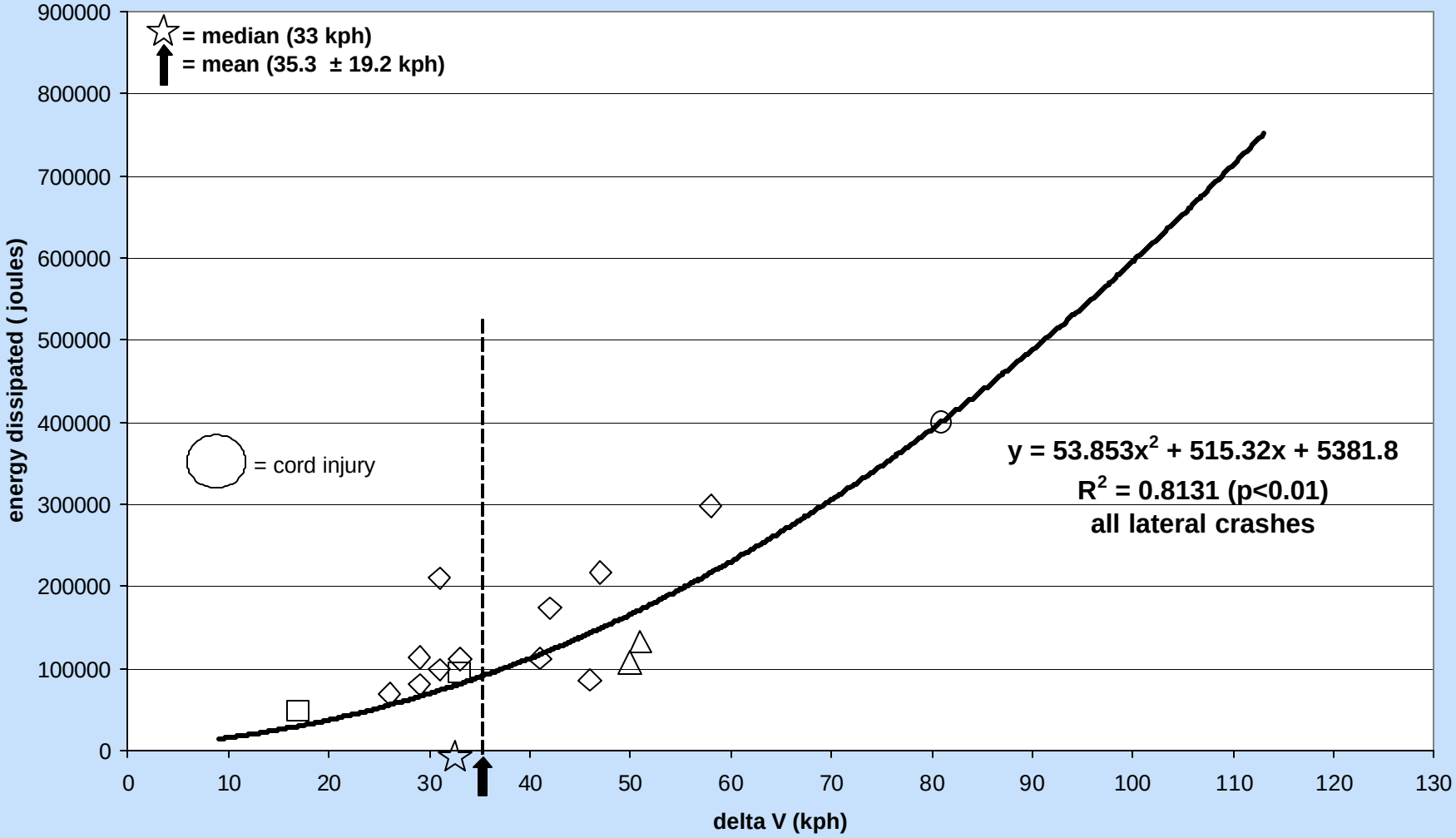
Patients With Lateral Lumbar Spine Injuries by Restraint Use and Mortality



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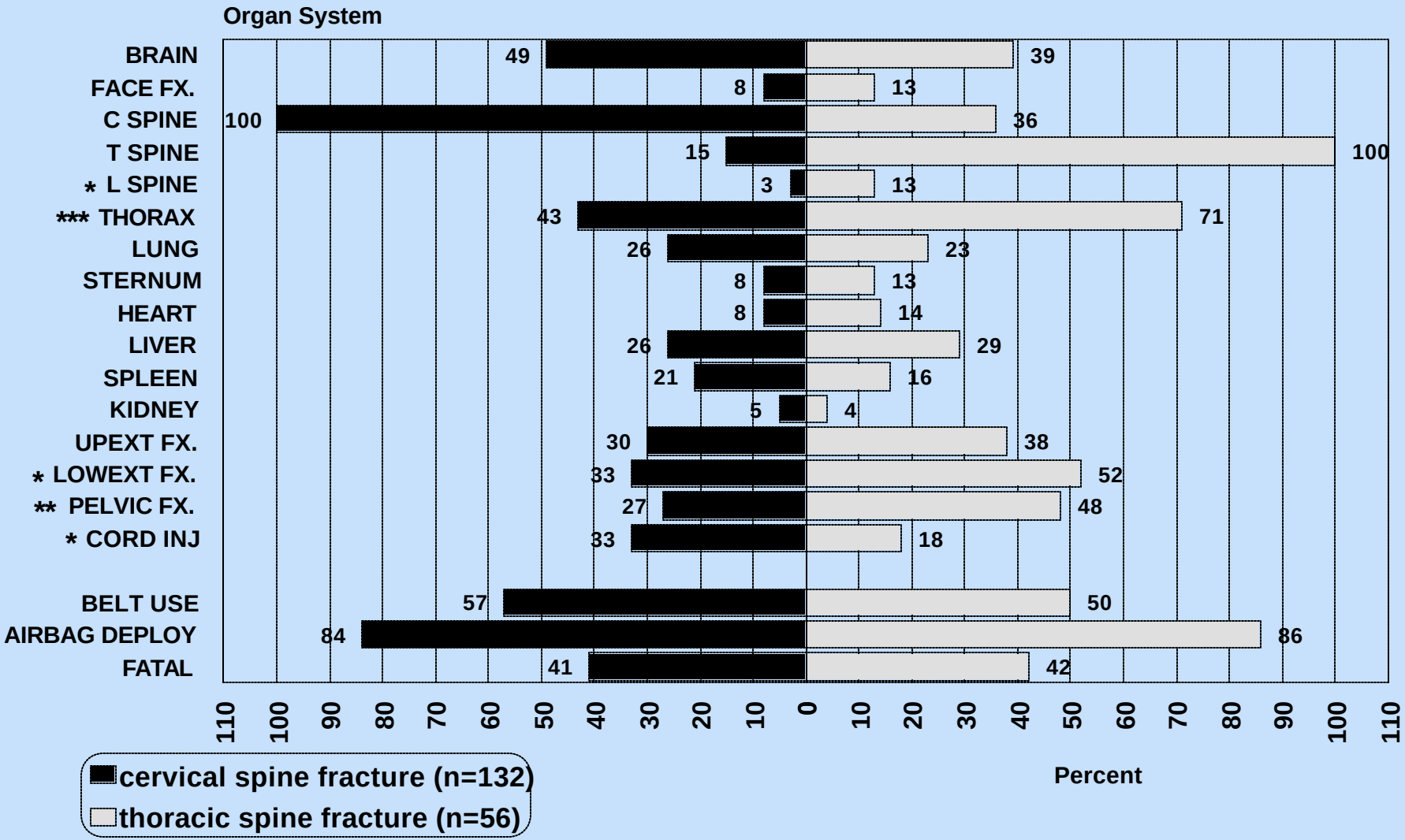
Patients With Cervical Spine Fractures vs Patients With Thoracic Spine Fractures



* = p<0.05
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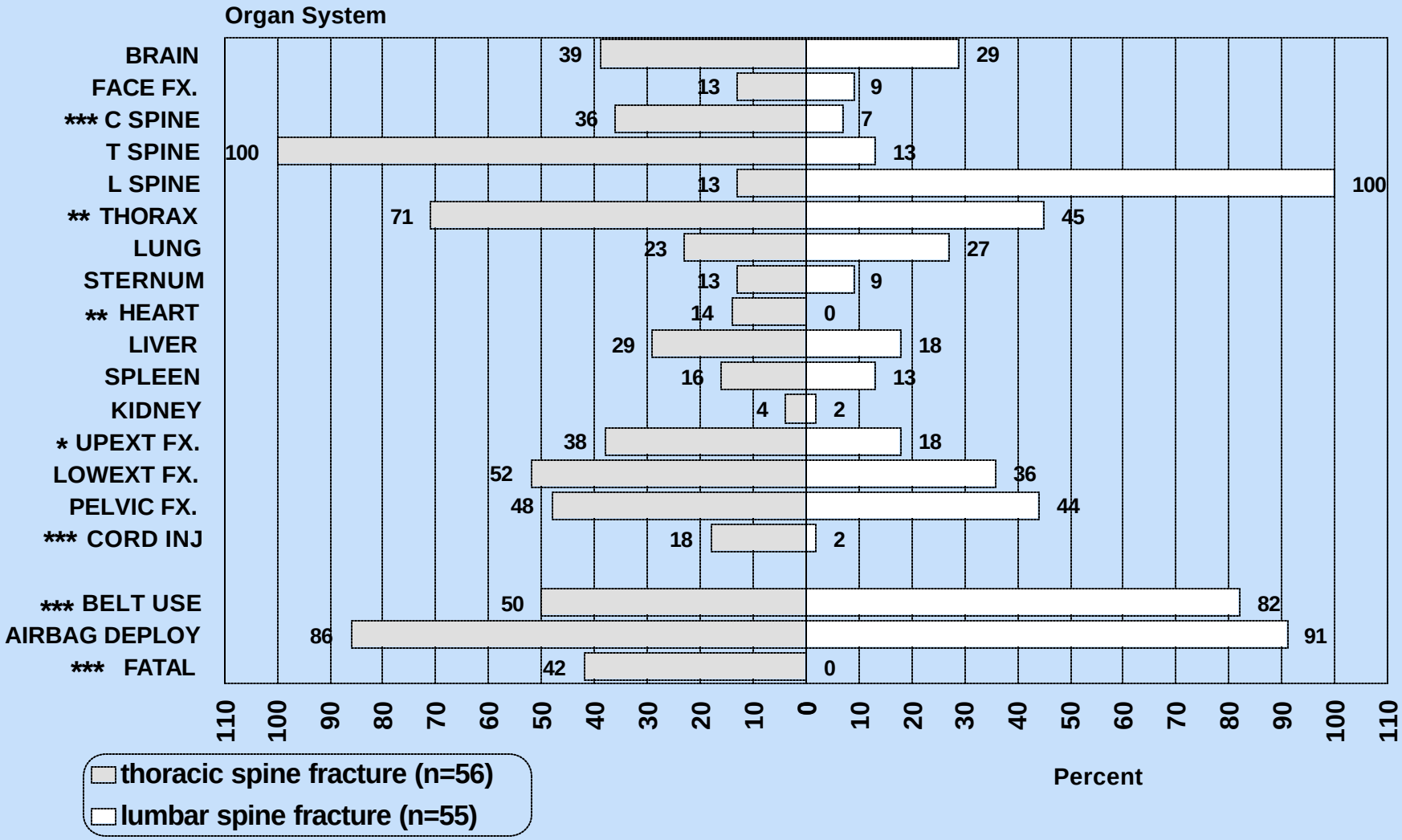
Patients With Thoracic Spine Fractures vs Patients With Lumbar Spine Fractures



* = p<0.05
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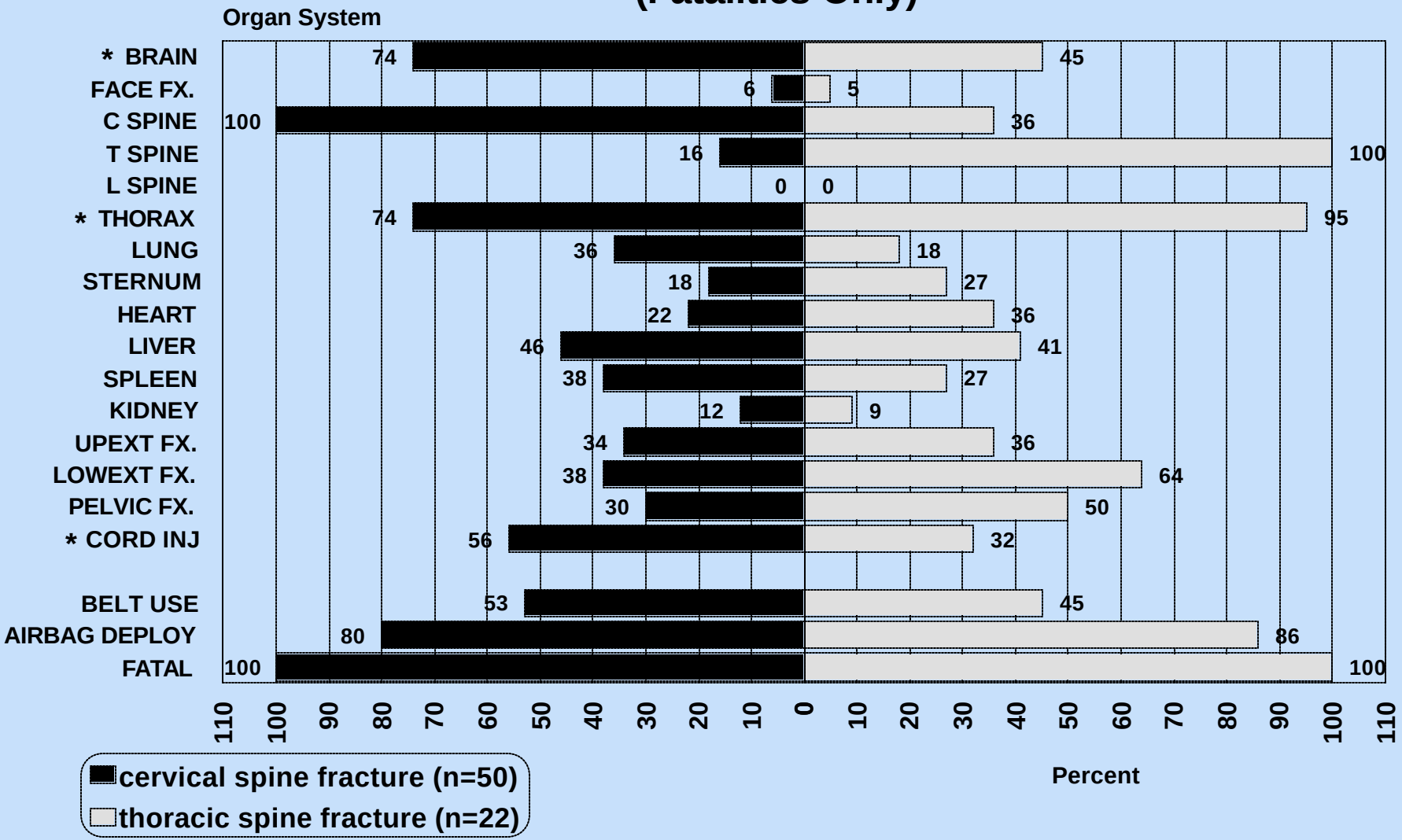
Patients With Cervical Spine Fractures vs Patients With Thoracic Spine Fractures (Fatalities Only)



* = p<0.05
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INCIDENCE OF SPINAL CORD INJURY(SCI) BY REGION OF SF

CERVICAL SCI 33%

THORACIC SCI 18%

LUMBAR SCI 2%

RELATIONSHIP OF SF & SCI TO DELTA V

FMVC DELTA V MEAN 47.4 KPH: 49% SF, 47% SCI AND 71% SF DEATHS OCCURRED ABOVE FMVC MEAN ? V

LMVC DELTA V MEAN 35.3 KPH: 51% SF, 52% SCI AND 67% SF DEATHS OCCURRED ABOVE LMVC MEAN ? V

OVERALL DEATH RATE IN C-SF 41%. HOWEVER, 80% OF ALL DEATHS IN SCI OCCURRED IN CERVICAL SF CASES AND IN THESE FATAL SF, 74% ALSO HAD A BRAIN INJURY.

OVERALL DEATH RATE IN Th-SF 42%. BUT, THORACIC SF DEATHS WERE MAINLY DUE TO BRAIN (45%), THORAX (95%), OR PELVIC FX (50%) INJURIES

SEAT-BELTS AND BACKLOADING INDUCTION OF LUMBAR, OR THORACIC SPINE FRACTURE WITH SPINAL CORD INJURY: CASE REPORTS

- **VEHICLE:** 1998 HONDA ACCORD IMPACTED CONCRETE BARRIER AT DELTA V OF 76 KPH WITH IE OF 363,060 JOULES

- **DRIVER:** 17 YEAR MALE, 5FT 8 INCH, 140 LBS; LAP-SHOULDER SB + AB; COMPRESSION FX L1 WITH L1/T12 FX DISLOCATION AND T12 SCI

- **FRONT-SEAT PASSENGER:** 16 YEAR FEMALE, 5FT 5 INCH, 120 LBS; LAP-SHOULDER SB + AB; BURST FX OF L4, NO SCI

- 3 REAR SEAT MALE PASSENGERS WEIGHING APPROXIMATELY 150 LBS EACH

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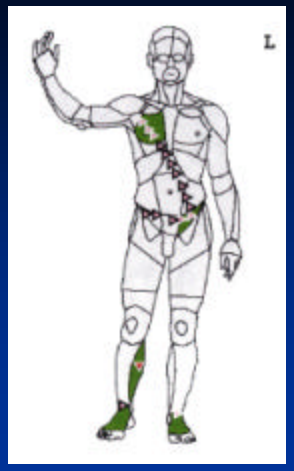
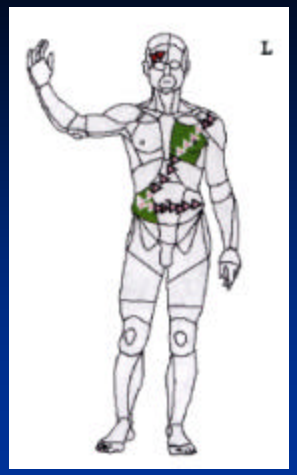
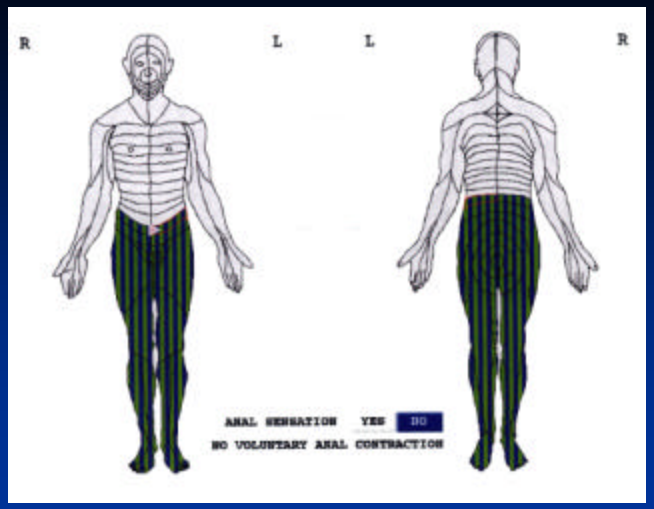
passenger



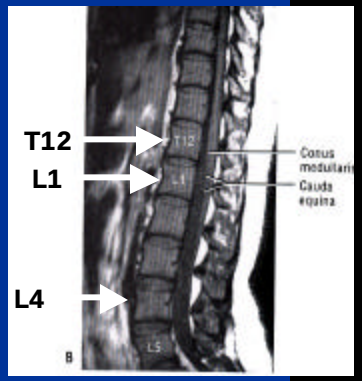
driver



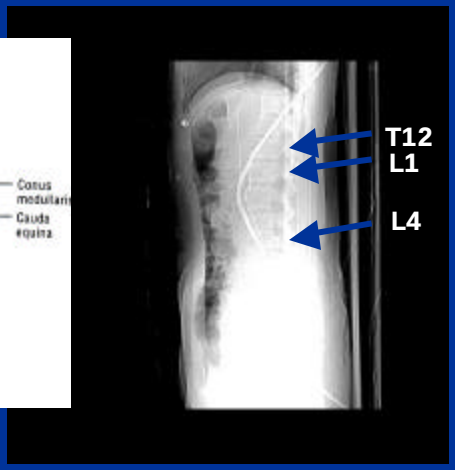
Seat belt contact marks, driver and passenger



Spinal cord injury, driver only



Normal spine and cord



Burst fracture L4 with intrusion into spinal canal

passenger

Normal spine and cord

Subluxation of L1 on T12

driver

Seatbelt+Backloading-Induced Thoracic Cord Injury

AIRBAG-INDUCED THORACIC SPINE FRACTURE DISLOCATION AND SPINAL CORD TRANSECTION

- **VEHICLE (V1):** 1997 MERCURY SABLE IN FMVC WITH 1989 FORD TAURUS STATION WAGON (V2) AT DELTA V OF 26 KPH WITH IE OF 47,803 JOULES

- **DRIVER:** 56 YEAR MALE, 5FT 10 INCH, 320 LBS; ANTERIOR CHEST WALL CLOSE TO STEERING WHEEL AB COVER; NO SB

- UNDEPOWERED AB DEPLOYED, PRODUCING FRACTURE DISLOCATION OF T4 ON T5 WITH COMPLETE MOTOR AND SENSORY LOSS DUE TO SPINAL CORD TRANSECTION

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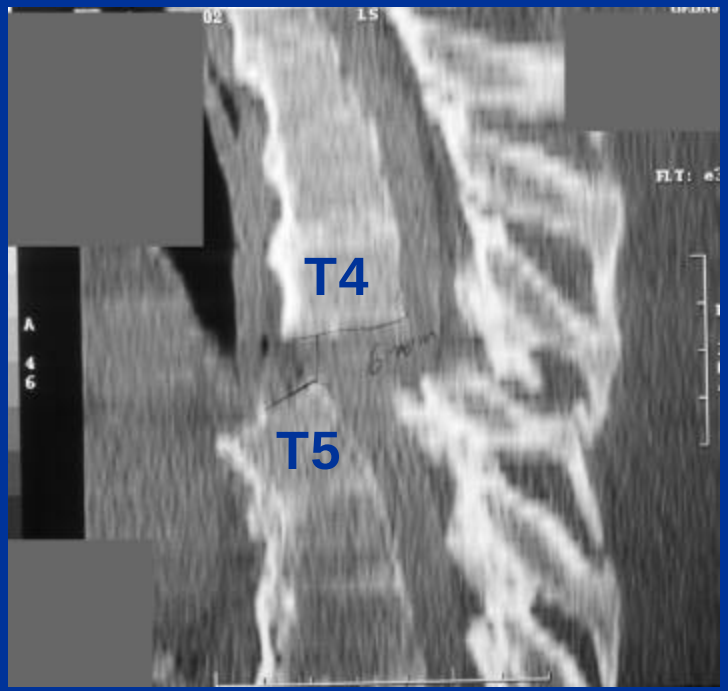

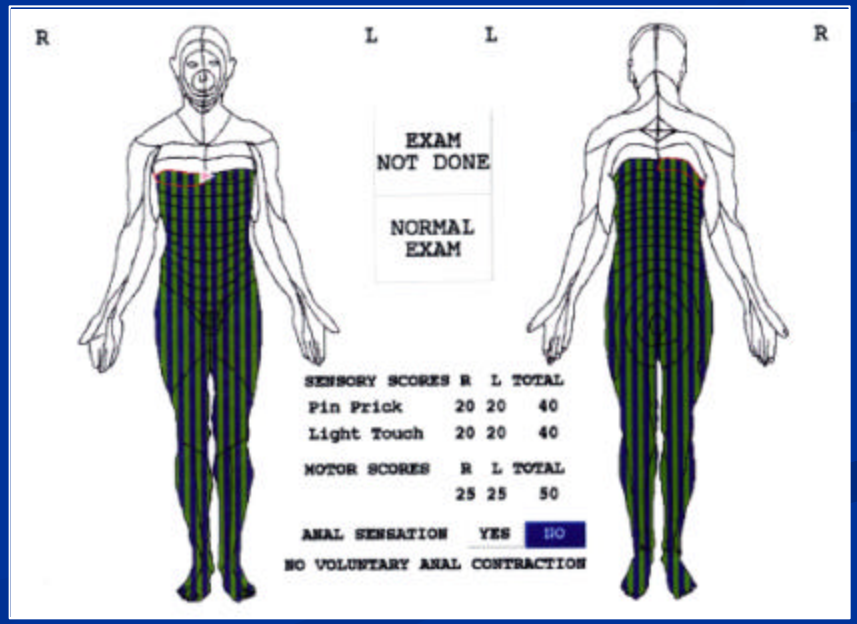

Airbag-Induced Thoracic Cord Injury

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AIRBAG-INDUCED CRANIAL-CERVICAL DISLOCATION AND CERVICAL SPINAL CORD TRANSECTION

• VEHICLE: 1993 FORD MUSTANG TWO-DOOR SPORT CONVERTIBLE (V1), STOPPED ON HIGHWAY, THEN STRUCK FROM BEHIND BY V2 (1996 NISSAN MAXIMA) AT HIGH SPEED WITH INTRUSION INTO REAR OF PASSENGER COMPARTMENT, PUSHING DRIVER INTO CONTACT WITH STEERING WHEEL AND UNDEPLOYED AIRBAG. THEN ROTATING V1 STRIKES V2 FRONTALLY, WITH ACTIVATION OF FRONTAL UNDEPOWERED AB, BEFORE COMING TO FINAL REST AGAINST A BARRIER.

• DRIVER: 31 YEAR FEMALE, 5 FT 4 INCH, 159 LBS; AB DEPLOYMENT PRODUCED CRANIO-CERVICAL DISLOCATION AT ATLANTO-OCCIPITAL JUNCTION WITH COMPLETE SPINAL CORD INJURY AND DISRUPTION/OCCLUSION OF BOTH INTERNAL CAROTIDS AND VERTEBRAL ARTERIES.

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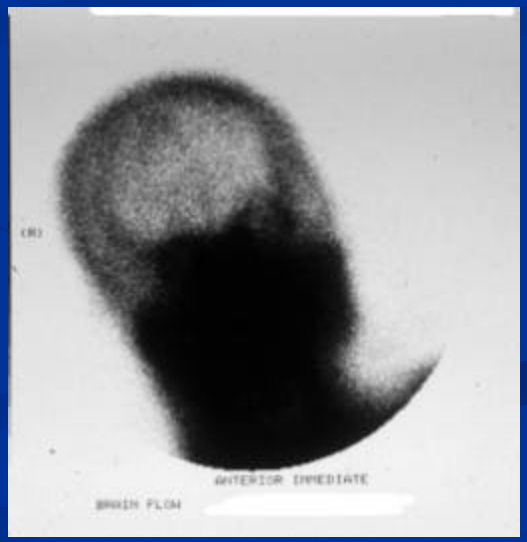

Airbag-Induced Cervical Cord Injury

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INFLUENCE OF RESTRAINT TECHNOLOGY: AIRBAGS & SEATBELTS

INCIDENCE OF SPINAL CORD INJURY AS PERCENTAGE OF SPINE FRACTURES BY VEHICLE MODEL YEAR PERIOD

FEW AB	AB USE	DEPOWERED AB
1989-1993	1994-1998	1999-2003
SCI 64%	SCI 54%	SCI 49%

INCIDENCE OF SEATBELT USE IN LUMBAR FRACTURE PATIENTS VS USE IN CERVICAL OR THORACIC FRACTURE PATIENTS:

% SB USE:

CERVICAL 57%, THORACIC 50%, LUMBAR 82%, ($p < 0.01$)

BACKLOADING BY REAR SEAT PASSENGERS, OR CARGO IDENTIFIED IN 20% OF LUMBAR SF PATIENTS

CONCLUSIONS I

THE MOST COMMON SPINE FRACTURE INJURY IN THIS SERIES APPEARED TO BE OF THE CERVICAL SPINE, AND THIS BONY INJURY ALSO APPEARED TO RESULT IN THE HIGHEST INCIDENCE OF SPINAL CORD INJURY.

WHILE RESTRAINT SYSTEMS, SB AND AB, APPEARED TO OFFER PROTECTION AND SURVIVAL BENEFIT TO PATIENTS WITH SF AND SCI IN FMVCS BELOW THE MEAN DELTA V LEVEL (47 KPH), THE PRESENT SB/AB SYSTEMS DID NOT SIGNIFICANTLY INCREASE PATIENT SURVIVAL ABOVE THIS CRITICAL THRESHOLD LEVEL IN PATIENTS WITH CERVICAL OR THORACIC SPINAL FRACTURES, ESPECIALLY IF THE CERVICAL SF WAS COMPLICATED BY A SPINAL CORD INJURY.

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CONCLUSIONS II

HOWEVER, IN THIS SERIES THE VAST MAJORITY OF FMVC SF PATIENTS HAD UNDEPOWERED ABs, AND THEIR SB WAS NOT EQUIPPED WITH A SEATBELT PRETENSIONER. THE EFFECTIVENESS OF SUCH NEWER DEVICES NEEDS TO BE EVALUATED IN THESE INCREASED DELTA V MVCs, WHERE THE INCIDENCE OF CERVICAL SF, SCI AND DEATH IS GREATLY INCREASED.

THERE WERE NO SIDE-CURTAIN ABs IN THIS SERIES AND THEIR BENEFICIAL EFFECTS IN PREVENTING CERVICAL SF AND SCI CAUSED BY LMVCs NEED TO BE SPECIFICALLY EXAMINED IN NEWER VEHICLES CONTAINING THESE IMPROVEMENTS.

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CONCLUSIONS III

FINALLY, THE INCREASED INCIDENCE OF THE ASSOCIATION OF THE INCORRECT PLACEMENT OF THE LAP PORTION OF THE LAP-SHOULDER SEAT BELT AND ITS RELATIONSHIP TO BACKLOADING FLEXION INJURIES OF THE LUMBAR AND LOWER THORACIC SPINE NEEDS TO BE FURTHER EXAMINED.

QUANTITATIVE BIOMECHANICAL STUDIES NEED TO BE DONE WITH RESPECT TO DEFINING THE RELATIONSHIP BETWEEN THESE TWO ENTITIES AND TO PROVIDE DATA THAT CAN ENHANCE THE DEVELOPMENT OF MORE EFFECTIVE MEASURES TO PREVENT BACKLOADING FLEXION INJURIES.

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Thank you for your attention!